

receiver filter functions 360 comprises output signals  $a^{(i)}(n)$  and  $a^{(j)}(n)$ .

These output signals may be switched at a rate of  $1/T$  to produce corresponding signals  $\hat{a}$  to  $i(n)$  and  $\hat{a}$  to  $j(n)$ .

Since  $H(f)$  is unknown, direct computation of  $P(f)$  is not feasible, since  
5 the matrix  $P(f)$  depends on the impairment matrix  $H(f)$ . However,  $P(f)$  is found based on iterative methods according to an embodiment of the invention. By starting with  $\tilde{P}(f)$  in place of  $P(f)$  and  $\tilde{P}(f)$  until the mean-square-error at the slicer of receiver 108 is minimized, then  $\tilde{P}(f)$  is a reasonable first approximation of  $P(f)$ .  $H(f)$  cannot necessarily be predicted accurately. A  
10 predetermined CAP signal has to be transmitted and the received CAP signal can be measured to determine errors in the received CAP signal.

Illustratively, for channel  $i$ , the transmitted CAP signal  $a^{(i)}(n)$ , after propagating through the channel, is sampled as  $a^{(i)}(n)$  at the receiver. The difference between the transmitted CAP signal and the received CAP signal is  
15 the difference error. The CAP signal for signal  $j$  causes interchannel interference with channel  $i$ . If the error is caused by the interference from channel  $j$ , through the cross-talk transfer function  $H_{ij}(f)$  (i.e., 345<sub>j</sub>), this error information can be used to adjust the pre-coder  $P_{ij}(f)$ , (i.e., 310<sub>j</sub>).

The two shaded paths in Figure 3 illustrate interchannel interference. In  
20 the first shaded path, transmit signal  $a^{(j)}(n)$  propagates through channel  $j$  by a path comprising summer function 320<sub>j</sub>, transmit filter function 330<sub>j</sub>, second channel impairment function 345<sub>j</sub> and data slicer function 350<sub>j</sub>. At second summer function 350<sub>i</sub>, the two CAP signal symbol streams are commingled and received via receiver function 360<sub>i</sub>.

25 The difference between the expected signal shape and level and the actual received signal shape and level is determined. In a second shaded path, a pre-coded CAP signal provided by pre-coder function 310<sub>j</sub> is propagated through a path comprising summer 320<sub>i</sub>, transmit filter function 330<sub>i</sub>, and first channel  $i$  impairment function 340<sub>i</sub> (i.e.,  $H_{ii}(f)$ ) and to second  $i$   
30 channel summer function 350<sub>i</sub>.

FIG. 3 shows that the effect of pre-coding transfer function  $P_{ij}(f)$  (310i) is to cancel the effect due to the cross-talk transfer function  $H_{ij}(f)$  (345j). The sum of the two paths should be zero. Specifically,  $P_{ij}$  is adjusted so that the difference between the two signals become zero. That is the two paths should have the opposite transfer function resulting in a sum of zero. Hardware and/or software suitable for realizing the pre-coder function may be implemented using techniques similar to those used for implementing an adaptive canceler.

FIG. 4 depicts a high level block diagram of a multiple channel transmission system according to an embodiment of the present invention. It will be appreciated by those skilled in the art that while the system 400 of FIG. 4 is depicted as including four encoding, transmitting and receiving entities, more or fewer encoding, transmitting and/or receiving entities may be utilized.

Each of the four transmitters depicted in FIG. 4 (denoted as channels A through D) comprises an encoder  $E$  that receives a respective bitstream or data signal or  $DS$  to be transmitted. The output of each encoder  $E$ , illustratively a CAP symbol stream of the form  $a^{(x)}(n)$ , where  $x$  identifies the particular channel, is coupled to a corresponding summer  $S$  and to the input of a pre-coder function within each of the other channels.

Each of three pre-coder functions (one for every other channel to be processed) used in each channel is used to adapt the encoded symbol stream to a respective one of the three remaining channels. The pre-coder functions are denoted as  $P_{xy}(f)$ , where  $x$  denotes the channel that utilizes the output of the pre-coder function, and  $y$  denotes the channel providing input to the pre-coder function. Thus, for example, pre-coder  $P_{12}(f)$  receives input from the encoder  $E_2$  of the second channel (i.e., channel B) and provides output to the summer  $S_1$  of the first channel (i.e., channel A).

Each summer  $S$  receives the output of its respective encoder  $E$ , as well as the output of a respective pre-encoder function ( $P_{12}(f)$ ,  $P_{13}(f)$  and  $P_{14}(f)$  in the case of channel A) from each of the three other transmission channels. The summer  $S$  sums the received signals to produce an output signal of the form

$v^{(i)}(n)$ , which is coupled to a transmit filter function  $G(f)$ . The output of transmit filter function  $G(f)$  is propagated to a respective receiver via a respective communications channel.

Referring to channel A in the system 400 of FIG. 4, the transmitter

5 includes an encoder  $E_1$  that produces an encoded symbol stream of the form  $a^{(1)}(n)$  in response to a received data signal  $DS_1$ . The encoded symbol stream is provided to a summer  $S_1$ . The summer  $S_1$  also receives three other signals provided by respective pre-coders. A first pre-coder  $P_{12}(f)$  receives an encoded signal  $a^{(2)}(n)$  produced by an encoder  $E_2$  of the second transmitter.

10 Similarly, the second  $P_{13}(f)$  and third  $P_{14}(f)$  pre-coders receive encoded signals from the third  $E_3$  and fourth  $E_4$  transmitters. Each of the pre-coders  $P_{12}(f)$  through  $P_{14}(f)$  provides a respective pre-coded output signal  $u^{(12)}(n)$  through  $u^{(14)}(n)$  to the summer  $S_1$ . The summer  $S_1$  sums the encoded signal produced by the encoder  $E_1$  and the signals produced by the three pre-coders

15 to produce an output signal  $v^{(1)}(n)$  that is coupled to the first transmitter filter  $G_1(f)$ . The output of the transmitter filter  $G_1(f)$  is transmitted by a respective channel to a corresponding receiver  $R_1(f)$ .

The transmission channels are depicted as having various channel impairments  $H(f)$ . Specifically, a transmission channel impairment  $H_{11}(f)$

20 operates upon data transmitted via the first transmission channel. Similarly, a second channel impairment  $H_{12}(f)$  represents the impairment to data within the first transmission channel caused by interference or cross-talk from the second transmission channel. A third impairment channel  $H_{13}(f)$  represents the impairment to data within the first transmission channel caused by

25 interference or cross-talk from the third transmission channel. A fourth impairment  $H_{14}(f)$  represents the impairment to data within the first transmission channel caused by cross-talk or interference from the fourth transmission channel.

Each of the channel impairments  $H_{11}(f)$  through  $H_{14}(f)$  are depicted as

30 being summed by a summer  $SH_1$ . It is noted that such summation does not actually exist as a discrete element; rather, the summation function  $SH_1$